**Chapter 23 Section 1 The Solar System**

**Key Concepts**

* How do terrestrial planets differ from Jovian planets?
* How did the solar system form?

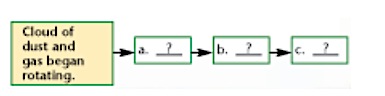
**Vocabulary**

* terrestrial planet
* Jovian planet
* nebula
* planetesimal

**Reading Strategy**

*Relating Text and Diagrams* As you read, refer to Figure 3 to complete the

flowchart on the formation of the solar system.



The sun is the hub of a huge rotating system of nine planets, their satellites, and

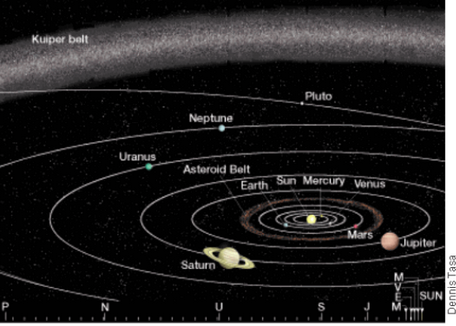
numerous smaller bodies. An estimated 99.85 percent of the mass of our solar

system is contained within the sun. The planets collectively make up most of the

remaining 0.15 percent. As Figure 1 shows, the planets, traveling outward from

the sun, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune,

and Pluto.



***Figure 1***

*Orbits of the Planets The positions of the planets are shown to scale along the bottom of the diagram.*

Guided by the sun’s gravitational force, each planet moves in an elliptical orbit, and all travel in the same direction. The nearest planet to the sun—Mercury— has the fastest orbital motion at 48 kilometers per second, and it has the shortest period of revolution. By contrast, the most distant planet, Pluto, has an orbital speed of 5 kilometers per second, and it requires 248 Earth-years to complete one revolution.

Imagine a planet’s orbit drawn on a flat sheet of paper. The paper represents the planet’s orbital plane. The orbital planes of seven planets lie within 3 degrees of the plane of the sun’s equator. The other two, Mercury and Pluto, are inclined 7 and 17 degrees, respectively.

**The Planets: An Overview**

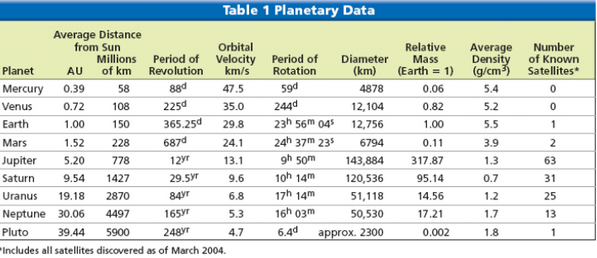
Careful examination of Table 1 shows that the planets fall quite nicely into two

groups. The terrestrial planets—Mercury, Venus, Earth, and Mars—are

relatively small and rocky. (Terrestrial = Earth-like.) The Jovian planets—

Jupiter, Saturn, Uranus, and Neptune—are huge gas giants. (Jovian = Jupiter-like.)

Small, cold Pluto does not fit neatly into either category.



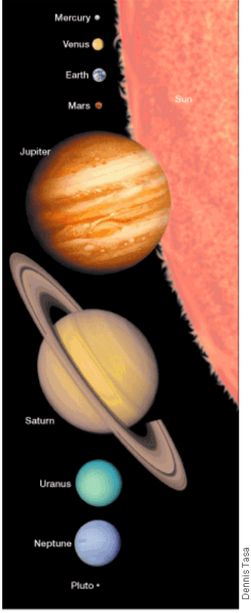
**Size is the most obvious difference between the terrestrial and the Jovian planets.**

The diameter of the largest terrestrial planet, Earth, is only one-quarter the diameter of the smallest Jovian planet, Neptune. Also, Earth’s mass is only 1/17 as great as Neptune’s. Hence, the Jovian planets are often called giants. Because of their distant locations from the sun, the four Jovian planets and Pluto are also called the outer planets. The terrestrial planets are closer to the sun and are called the inner planets. As we shall see, there appears to be a correlation between the positions of these planets and their sizes.

**Density, chemical makeup, and rate of rotation are other ways in which the two groups of planets differ.** The densities of the terrestrial planets average about

five times the density of water. The Jovian planets, however, have densities that average only 1.5 times the density of water. One of the outer planets, Saturn, has a density only 0.7 times that of water, which means that Saturn would float if placed in a large enough water tank. The different chemical compositions of the planets are largely responsible for these density differences.

**The Interiors of the Planets**

The planets are shown to scale in Figure 2. The substances that make up the planets are divided into three groups: gases, rocks, and ices. The classification of these substances is based on their melting points.

***Figure 2*** *The planets are drawn to scale. Interpreting Diagrams How do the sizes of the terrestrial planets compare with the sizes of the Jovian planets?*

1. The gases—hydrogen and helium—are those with melting points near absolute zero (-273°C or 0 kelvin).

2. The rocks are mainly silicate minerals and metallic iron, which have melting points above 700°C.

3. The ices include ammonia (NH3), methane (CH4), carbon dioxide (CO2), and water (H2O). They have intermediate melting points. For example, H2O has a melting point of 0°C.

The terrestrial planets are dense, consisting mostly of rocky and metallic substances, and only minor amounts of gases and ices. The Jovian planets, on the other hand, contain large amounts of gases (hydrogen and helium) and ices (mostly water, ammonia, and methane). This accounts for their low densities.

The outer planets also contain substantial amounts of rocky and metallic

materials, which are concentrated in their cores.

**The Atmospheres of the Planets**

The Jovian planets have very thick atmospheres of hydrogen, helium, methane, and ammonia. By contrast, the terrestrial planets, including Earth, have meager atmospheres at best. A planet’s ability to retain an atmosphere depends on its mass and temperature, which accounts for the difference between Jovian and terrestrial planets. Simply stated, a gas molecule can escape from a planet if it reaches a speed known as the escape velocity. For Earth, this velocity is 11 kilometers per second. Any material, including a rocket, must reach this speed before it can escape Earth’s gravity and go into space. A comparatively warm body with a small surface gravity, such as our moon, cannot hold even heavy gases, like carbon dioxide and radon. Thus, the moon lacks an atmosphere. The more massive terrestrial planets of Earth, Venus, and Mars retain some heavy gases. Still, their atmospheres make up only a very small portion of their total mass.

In contrast, the Jovian planets have much greater surface gravities. This gives them escape velocities of 21 to 60 kilometers per second—much higher than the terrestrial planets. Consequently, it is more difficult for gases to escape from their gravitational pulls. Also, because the molecular motion of a gas depends upon temperature, at the low temperatures of the Jovian planets even the lightest gases are unlikely to acquire the speed needed to escape.

**Formation of the Solar System**

Between existing stars is “the vacuum of space.” However, it is far from being a

pure vacuum because it is populated with clouds of dust and gases. A cloud of

dust and gas in space is called a nebula (nebula = cloud; plural: nebulae). A

nebula, shown in Figure 3A, often consists of 92 percent hydrogen, 7 percent

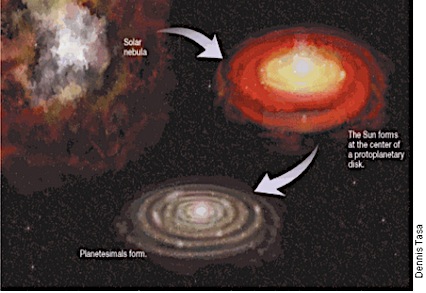
helium, and less than 1 percent of the remaining heavier elements. For some

reason not yet fully understood, these thin gaseous clouds begin to rotate slowly

and contract gravitationally. As the clouds contract, they spin faster. For an

analogy, think of ice skaters—their speed increases as they bring their arms

near their bodies.

**Figure 3 *Formation of the Universe***

***A*** *According to the nebular theory, the solar system* formed from a rotating cloud of dust and gas.

**B** The sun formed at the center of the rotating disk.

**C** Planetesimals collided, eventually gaining enough mass to be planets.

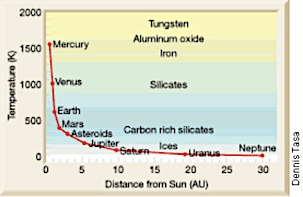
**Nebular Theory**

Scientific studies of nebulae have led to a theory concerning the origin of our solar system. **According to the nebular theory, the sun and planets formed from a rotating disk of dust and gases.** As the speed of rotation increased, the center of the disk began to flatten out, as shown in Figure 3B. Matter became more concentrated in this center, where the sun eventually formed.

**Planetesimals**

The growth of planets began as solid bits of matter began to collide and clump together through a process known as accretion. The colliding matter formed small, irregularly shaped bodies called **planetesimals**. As the collisions continued, the planetesimals grew larger, as shown in Figure 3C on page 647. They acquired enough mass to exert a gravitational pull on surrounding objects. In this way, they added still more mass and grew into true planets.

In the inner solar system, close to the sun, temperatures were so high that only metals and silicate minerals could form solid grains. It was too hot for ices of water, carbon dioxide, and methane to form. As shown in Figure 4, the inner planets grew mainly from substances with high melting points.



***Figure 4*** *The terrestrial planets formed mainly from silicate minerals and metallic iron that have high melting points. The Jovian planets formed from large quantities of gases and ices.*

In the frigid outer reaches of the solar system, on the other hand, it was cold enough for ices of water and other substances to form. Consequently, the Jovian planets grew not only from accumulations of solid bits of material but also from large quantities of ices. Eventually, the Jovian planets became large enough to gravitationally capture even the lightest gases, such as hydrogen and helium. This enabled them to grow into giants.

**Chapter 23 Section 1 Assessment Questions**

**Reviewing Concepts**

(1) Which planets are classified as terrestrial? Which planets are classified as

Jovian?

(2) Sequence the nine planets in order, beginning with the planet closest to the sun.

(3) How do the terrestrial planets differ from the Jovian planets?

(4) What is a nebula?

(5) How did distance from the sun affect the size and composition of the planets?

**Critical Thinking**

(6) **Summarizing** Summarize the nebular theory of the formation of the solar

system.

(7) **Inferring** Among the planets in our solar system, Earth is unique because water

exists in all three states—solid, liquid, and gas—on its surface. How

would Earth’s water cycle be different if its orbit was outside the orbit

of Mars?

**Chapter 23 Section 1 Assessment Questions**

**Reviewing Concepts**

(1) Which planets are classified as terrestrial? Which planets are classified as

Jovian?

(2) Sequence the nine planets in order, beginning with the planet closest to the sun.

(3) How do the terrestrial planets differ from the Jovian planets?

(4) What is a nebula?

(5) How did distance from the sun affect the size and composition of the planets?

**Critical Thinking**

(6) **Summarizing** Summarize the nebular theory of the formation of the solar

system.

(7) **Inferring** Among the planets in our solar system, Earth is unique because water

exists in all three states—solid, liquid, and gas—on its surface. How

would Earth’s water cycle be different if its orbit was outside the orbit

of Mars?